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Construction and Operation of Butterfly Insectaries in the Tropics[1]

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(Plates I-V; Text-figures 1 & 2)

[This paper is one of a series emanating from the tropical Field Station of the New York Zoological Society at Simla, Arima Valley, Trinidad, British West Indies. This station was founded in 1950 by the Zoological Society's Department of Tropical Research, under the direction of Dr. William Beebe. It comprises 200 acres in the middle of the Northern Range, which includes large stretches of undisturbed government forest reserves. The laboratory of the station is intended for research in tropical ecology and in animal behavior. The altitude of the research area is 500 to 1,800 feet, with an annual rainfall of more than 100 inches.

[For further ecological details of meteorology and biotic zones see "Introduction to the Ecology of the Arima Valley, Trinidad, B. W. I.," William Beebe, (Zoologica, 1952, Vol. 37, No. 13, pp. 157-184).

[A two weeks' field trip in Surinam, mentioned in the present contribution, was undertaken in April, 1953, had headquarters at the Moengo mine of the Surinaamsche Bauxite Maatschappij and was made possible through a grant from the Explorers' Club and through the cooperation of the Aluminum Corporation of America.]

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I. Introduction

The insectaries described in the following pages were designed primarily for perennial studies on the behavior of tropical butterflies. Their design and operation naturally differ in many respects from those of structures erected in northern climates and intended for breeding, rearing, temporary public exhibition or brief experiments. As studies similar to ours have apparently not previously been made, it seems desirable to present in some detail the designs and methods which we have used successfully in Trinidad and Surinam for the past three years.

In the literature it appears that only the studies of Ilse (1928 ff.) in Germany and Tinbergen and his associates (1943) in the Netherlands resemble our own, both in method and purpose. These workers performed painstaking and illuminating experiments on the roles of color, form and odor in the behavior of butterflies, in the field as well as in captivity. Ilse first used part of a greenhouse; later both she and the Tinbergen group erected flat-topped cages out-of-doors, which gave ample flying space; only light construction was necessary because of the short-term character of the experiments. Tinbergen's cage of cloth netting measured 5 × 2 ×2 meters and is figured (1943, p. 189); construction data on Ilse's later open-air cages have apparently not been published.

Peterson (1944) discusses and figures various types of spacious, sturdily-built field insectaries, suitable for rearing or experimental work on various orders of insects. However, they are designed for the keeping of small cages under more or less natural meteorological conditions; as will be shown below, their roofs, floors and partly solid walls do not adapt them to free-flying tropical butterflies.

A number of authors have described the successful maintenance of stocks of various species. David & Gardiner (1952) report a method of rearing *Pieris brassicae* Linnaeus and *Apanteles glomeratus* Linnaeus through successive generations indoors, even during English winters. These workers emphasize two essentials which hold true under the very different conditions of our own studies, namely the necessity for abundant light on all sides of the cage and for adequate real or simulated sunlight. The cages measured 40 × 30 × 36 inches. Because the authors' sole purpose was conveniently to maintain a constant supply of imagos for testing insecticides, they needed only space enough to induce these particular species to feed from artificial flowers, mate and oviposit.

Similar success has occasionally been reported by various authors who describe a variety of butterfly breeding methods for a number of restricted scientific or commercial purposes. Helpful suggestions for the keeping of adults alive will be found especially in Gerould (1911), Olivier (1926), Reinhard (1929), Blunck (1935), Norris (1935), Swingle (1935), Macy (1936) and Newman (1953). Through all these references it is apparent that space and environment needs, even in order only to induce copulation and oviposition, vary with the species. Many do well in small boxes with only one or two sides covered with netting; others have not yet been induced to breed in captivity.

As we are studying normal behavior patterns, our aim in Trinidad has been to approximate natural conditions closely enough so that the butterflies will not merely feed, mate and oviposit but so that their flight patterns, courting and other social activities take as normal a course as possible. Everyone who has observed living butterflies knows how fragmentary are the patterns that may be observed out in the open. Food preferences are rather easily learned, but the scarcity of descriptions in the literature of butterfly courtships, to give one example, shows the difficulty of this kind of work. On the other hand, when butterflies are merely bred, through keeping them under conditions just adequate to induce copulation, the courting patterns are so curtailed and distorted that no proper study can be made of them. Our compromise with space between small breeding cages and natural environments, has given us to date more or less satisfactory results in about thirty-five species. With some of these we have been successful, our progress in studies of their behavior being limited only by the time we are able to devote to the work. In several species, generations follow one another with little care from us, the insects appearing excellently adapted to the life of captivity; as an example one individual *Heliconius erato hydara* Hewitson, of the F2 generation, lived more than three months in the adult stage. At the other extreme are a number of species, notably the ithomiines, which so far have survived only several days in the insectaries.

The present paper is a preliminary report on general methodology which will be followed by publications on experimental techniques and the behavior of various species. It represents a threefold division of labor on the part of the Department of Tropical Research. Dr. William Beebe should properly be one of the co-authors; it was he who made plans for building tropical insectaries for behavior studies years before the establishment of the Simla field station made their actual construction possible; in fact, one reason for the selection of the locality was its suitability for such studies. Since then Dr. Beebe has directed and been vitally concerned in every phase of the work. Of the present authors, Fleming has been responsible for the design and construction of the insectaries, while Crane has been concerned with the establishment of optimum ecological conditions inside the structures and with methods of maintaining the populations.

Our deep appreciation goes to Mr. Samuel Ordway, Jr., and Mr. C. R. Vose for the generous contributions which made possible the construction of the insectaries.

II. Construction

Peterson (1944, Pt. 1, pp. 1-3) has emphasized the continuing need of detailed accounts both of apparatus construction and of methods. Accordingly, in this section is given a somewhat full account of the building of the insectaries, even though the details may appear elementary to some and to others rather foreign to biology. The presentation has seemed desirable since many biologists are not trained in construction techniques and, particularly in the tropics, are often confronted with unfamiliar practical difficulties along with inadequate time, funds and trained labor.

As described in the introduction, the object of our insectaries has been to enclose tropical butterflies under conditions as nearly natural as possible. Probably the greatest single factor in attaining this end is the provision of sufficient flying space.

We do not consider that a cage smaller than 12′ × 15′ is serviceable. We had an insectary of this size constructed for a short two-week stay in Surinam (Pl. III, Fig. 5). The cage had the advantages that it was small enough to be easily moved from place to place, and it required in comparison to large cages relatively little construction material and few work hours, thus minimizing the expense and time necessary to construct it. Nevertheless it had two drawbacks: while the insects acclimated themselves, the crowding was unnatural and overstimulated them, and the working area for the biologist was very limited.

On the other hand, the large insectary (24′ × 33′) at Simla in Trinidad was more expensive to construct, required a considerably greater expenditure of time and would be quite difficult to move (Pl. I; Pl. II, Fig. 3). Its size, however, permits excellent duplication of natural conditions and due to the flight habits of some species we are interested in, is the only satisfactory size. This cage may be the maximum size advisable. Forgetting all other considerations, it is most difficult for the biologist to move the length of the insectary to keep his subject under observation when the butterfly has such a large area at its disposal. To put it another way, if the insectary were larger, it would probably be no more difficult to observe the insect in the field. Such an enlarged cage would have only the advantage of confining the insect so that it would be obtainable if desired as a specimen. Even this would be of dubious value, since it is surprisingly difficult to locate any motionless insect even in our 24′ × 33′ structure.

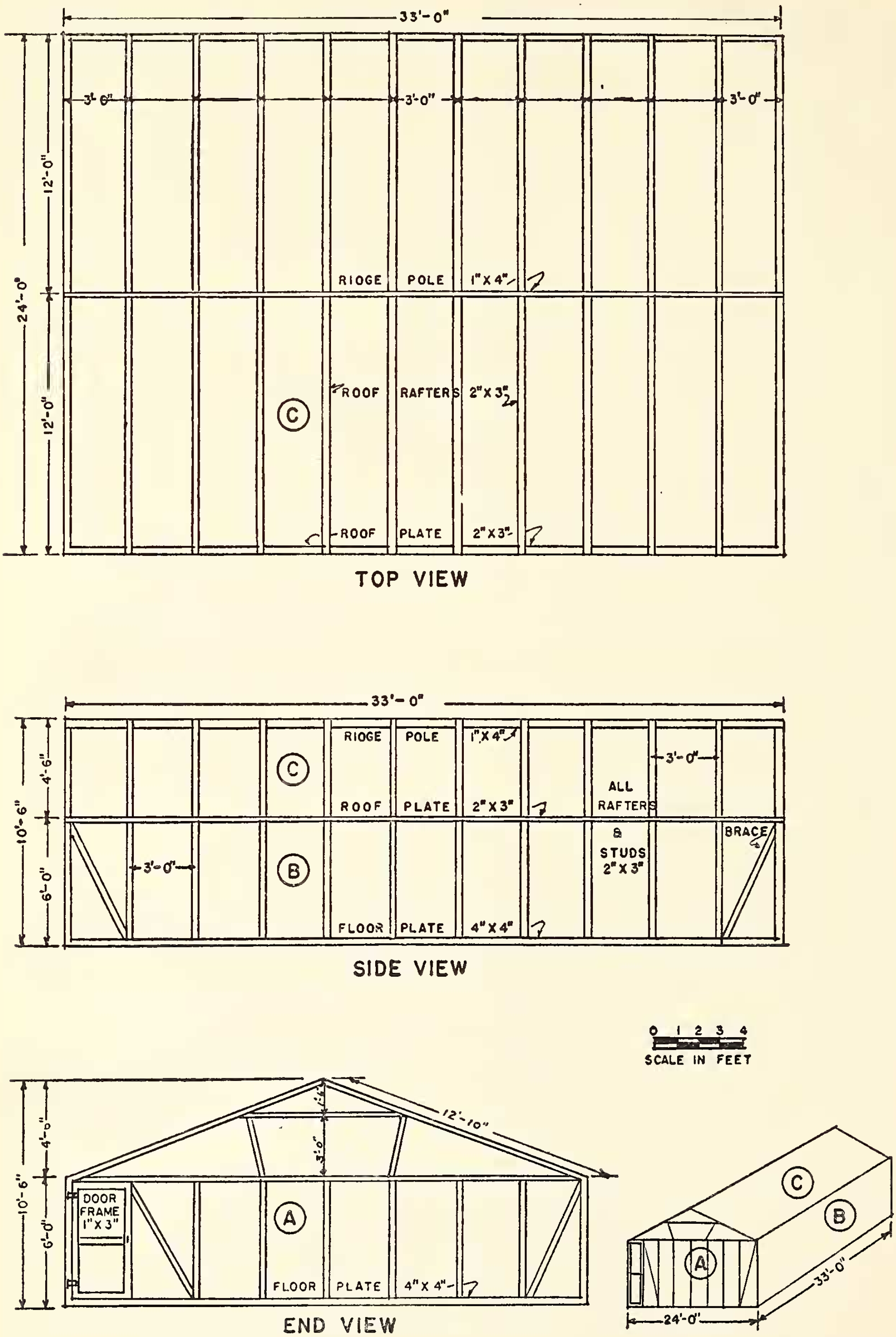
Our small insectary (12′ × 18′) at Simla was intended as a trial model (Pl. II, Fig. 4). It proved to be so successful that the larger one was built the following year. Our initial thought that the larger would supercede the smaller cage has turned out to be wrong, as the two complement each other. For instance, the small insectary is of great value when we wish to isolate for special study one or more butterflies. It has also been useful as an insect photographic laboratory. Furthermore, certain groups of butterflies and problems are more conveniently handled in the smaller area. Finally, all the insects may be transferred into one or the other in an emergency, such as an army ant infestation.

The foundations for both of the Trinidad insectaries were constructed by first digging a shallow trench to a maximum depth of one foot. Since at this depth we had reached bed rock, albeit a somewhat decayed and porous limestone, we had a firm base upon which to pour a concrete footing eight inches in depth and twelve inches wide. We raised the foundation upon this to a suitable height with hollow clay tiles. The foundation was kept to two or three inches above ground level where possible, any raised foundation being made only to provide a level bed upon which to rest the structure. If the insectary is to be permanent, a foundation of this nature is important not only to prevent settling with the consequent sagging of the frame but also to raise the wooden sill above the continual dampness of the ground. In addition, insects such as termites are less apt to discover the wood if it is raised above the ground, and, if they do, are much easier to discover and eradicate. The use of hollow clay tile is of course optional. We used it in Trinidad because it was available and saved us time and labor. Forms could be built and the whole foundation made of poured concrete or the foundation could be constructed of field stone. Time, labor, materials available and ingenuity are the limiting factors.

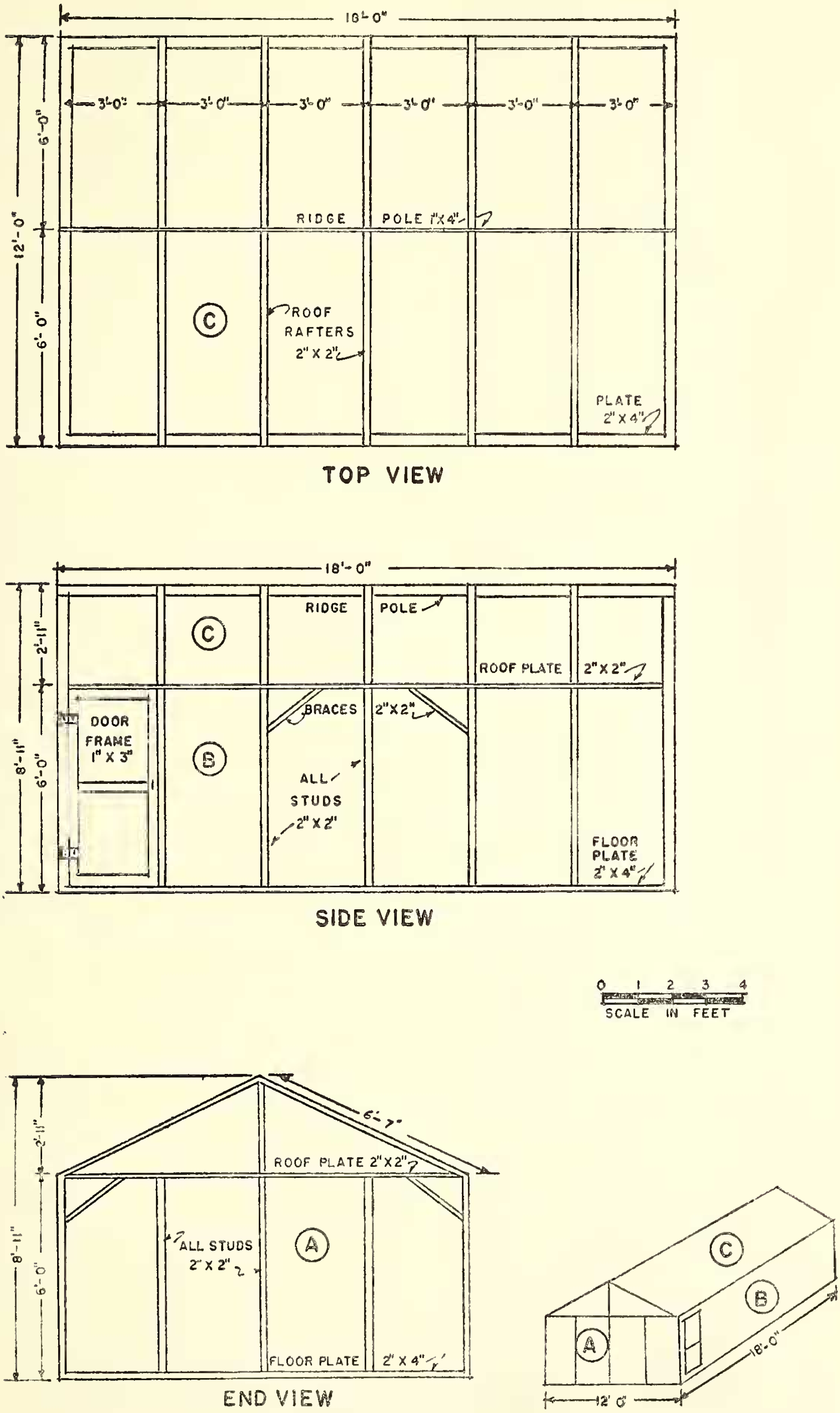
The remainder of the work is in the field of carpentry. If a carpenter is at hand, he can build the insectary from the plans we illustrate (Text-figs. 1, 2 & Tables 1, 2) or adapt them to fit different conditions. Frequently in the tropics, at least away from metropolitan centers, the carpenter is more of a handyman than a carpenter and is unable to read and write, let alone read plans. On the other hand he may be very skillful with the saw and hammer if he is told where to use them. With this in mind the following details may be of assistance.

The floor plate which is also doing duty as a sill may be joined at the corners or at the ends and sides where the lumber is not long enough to cover the required distance with a half-lap mortise. At the corner, for instance, cutting each of the floor plates halfway through on opposite sides and removing the surplus wood from the cut to the end, lapping them together and securing them with two ten-penny nails is sufficient. Along the sides or ends six to twelve inches of wood had best be removed. The floor plate may be fastened to the foundation with bolts set in the concrete of the foundation and passing through the plate if desired. We did not find this procedure necessary.

For the large insectary, because of the weight of the 4 × 4s we used as floor plates, we set the floor plates in place on the foundation and assembled the remainder of the sides and ends of the insectary separately. In other words, we squared a line across the roof plate every three feet and nailed the studs to the roof plate at these points. Care must be taken that the middle line of each stud falls three feet from the middle line of the neighboring stud, otherwise screening of three-foot width will not fit. However, if the screening is of different dimension than three feet, then the studding must be the cor-



TEXT-FIG. 1. Large Insectary.



TEXT-FIG. 2. Small Insectary.

TABLE 1. MATERIALS LIST FOR LARGE INSECTARY

No. of pieces	Dimensions of lumber	Member
2	4″ × 4″ × 16′	side floor plates
2	4″ × 4″ × 18′	
2	4″ × 4″ × 16′	end floor plates
1	4″ × 4″ × 18′	
42	2″ × 3″ × 6′	studs
2	2″ × 3″ × 16′	side roof plates
2	2″ × 3″ × 18′	
2	2″ × 3″ × 16′	end roof plates
1	2″ × 3″ × 18′	
24	2″ × 3″ × 14′	rafters
2	2″ × 3″ × 16′	tie beams
1	2″ × 3″ × 18′	
4	2″ × 3″ × 14′	stud braces
1	1″ × 4″ × 16′	ridgepole
1	1″ × 4″ × 18′	
1	1″ × 4″ × 9′	door
1	1″ × 4″ × 12′	
4	2″ × 3″ × 14′	rafter braces

560 linear feet of bronze screening
8 lbs. eight-penny common nails
4 lbs. ten-penny common nails
1 lb. five-eighths-inch copper tacks
1 pair of hinges
1 door latch
Amount of masonry materials varies with site

responding dimension on center. We would not advise screening of a greater width than thirty-six inches as the screening would have a tendency to sag—unless, for instance, with screening forty-eight inches wide one is willing to place the studs two feet on center. After the studs for the sides and ends of the insectary have been nailed to their respective roof plates, these units may be carried to the floor plate already in position on the foundation and secured to it. Temporary braces should be used to hold the studs, particularly at the corners, perpendicular to the floor plate. The studs on the corners should be doubled. In other words if 2 × 3s are being used, two studs should be nailed together so that the corner studs measure 4″ × 3″.

Two struts should now be set in place, holding the long sides together. These struts are not shown in the plans (Text-figs. 1, 2), as the rafters hide them. They should be placed across the plates nine feet from each end in the large cage and six feet from the ends in the small cage, though in the latter they are not altogether necessary. They are used to keep the sides of the structure from spreading and in the large insectary are supported by two posts set in the ground. The permanent braces for the studs may now be put in place and the temporary braces removed.

A gable roof rather than a flat roof is recommended. Our experience with a flat roof has been that rainwater tends to settle in sags in the screening and come pouring through into the cage as if from a faucet. The slope of a gable roof distributes the rain evenly within the enclosure.

In the event that the carpenter is not familiar with the use of a steel square, the easiest way to determine the angle to saw the rafters where they join the ridgepole and roof plates is as follows: Find the mid-point of one end of the floor plates and mark it. Place one end of the lumber to be used as a rafter at this point and the other end along the floor plate making up one side of the insectary, at a point which will give the desired pitch. A line drawn across the rafter at right angles to the floor plate at the end of the insectary, and a line drawn across the rafter along the outside of the floor plate of the side of the insectary, give the correct lines to be followed in sawing. Allowance must be made for the thickness of the ridgepole. In our case the ridgepole was one inch thick so the line at the end of the insectary was made a half-inch away from the actual mid-point line.

When one rafter is sawed, it should be used as a pattern for the rest of the rafters and they may be all similarly sawed. One must be careful to use the same rafter, as otherwise, some rafters will be longer than desired. Two pairs of rafters should have nails started in the ends. Each rafter may then be lightly nailed to the roof plate, one pair of rafters at the front end of the insectary and the other at a convenient distance towards the back to balance the ridgepole. The ridgepole

TABLE 2. MATERIALS LIST FOR SMALL INSECTARY

No. of pieces	Dimensions of lumber	Member
2	2″ × 4″ × 18′	side floor plates
2	2″ × 4″ × 12′	end floor plates
24	2″ × 2″ × 6′	studs
2	2″ × 2″ × 18′	side roof plates
2	2″ × 2″ × 12′	end roof plates
2	1″ × 4″ × 18′	rafters
7	2″ × 2″ × 14′	door and ridgepole
5	2″ × 2″ × 6′	braces and ridgepole stud

211 linear feet of bronze screening
6 lbs. of eight-penny common nails
⅜-lb. five-eighths-inch copper tacks
1 pair of hinges
1 door latch
Amount of masonry materials varies with site

may then be introduced and all firmly nailed. The remaining rafters should be nailed, with care being taken to space them accurately.

After the end braces are set in place, the screening may be tacked on. If it is desired to make a neater and somewhat stronger job, furring strips may be placed over the screen seams. However, if the region is damp, furring strips would cause rotting of the studs and rafters because of the water that would settle underneath. There is also the danger of undesirable organisms establishing themselves in the crevices.

Fine-mesh bronze screening was used to close the insectary. While bronze was more expensive than galvanized screening, the advantages of having a netting that did not rust more than compensated us for the higher initial cost. Screens made of other materials such as aluminum and plastic are available, but we so far have had no experience with them. Since we wished to avoid the initial glare of bronze screening, we purchased a type with "antique finish." This was very unfortunate as the finish used to dull the bronze was fatal to the butterflies, and four to six weeks of weathering proved necessary to remove the injurious agent. On the other hand, no difficulty whatsoever was experienced with the ordinary bronze screening used in Surinam.

Both the large and small insectaries were constructed at minimum cost compatible with reasonable durability. The roof plate in each of the cages could be doubled and additional braces introduced in the studding and rafters if desired. As a matter of fact, if the large insectary were to be built in an area of snowfall, additional bracing and stouter rafters would be absolutely requisite. However, as we have constructed these cages, we expect them, with only occasional attention, to give at least ten years of service. In our own case we consider the resistance of the wood members to various types of tropical decay to be our greatest limiting factor. We use no wood preservatives, although they are usually considered imperative in the tropics, because of the obvious danger of poisoning our selected insects. In slightly more than three years it has been necessary to replace only one rafter in the small insectary. This rafter had previously been split by a falling branch, which allowed fungi to enter the wood.

Various vines which have been used to control humidity and shade have had to be pruned periodically to prevent dampness and subsequent rotting of studs and rafters.

Continual vigilance is necessary to prevent termite damage. If colonies of termites are not allowed to establish themselves, the difficulty of eradicating them and consequent damage to the structure is negligible. Usually it is only necessary to destroy the tunnels about the foundation and remove any termite nests in the immediate vicinity of the insectaries. On one occasion we had a bad infestation in a rafter of the small insectary and employed a commercial product of DDT in water. It was necessary to remove the butterflies for one week. At Simla this period was considered sufficient time for the DDT to have dissipated itself because of the heavy rains. Usually the best method is to replace the damaged members of the structure. Though the DDT proved effective on the occasion we used it, we do not recommend its use because of its residual nature. If it is inconvenient to replace any of the structure, it is better to drill the necessary number of small holes in the infested wood and squirt in light machine oil with an oil can. Care must be taken to insert the oil neatly and not leave the outside of the wood impregnated with oil. Some woods are in varying degrees resistant to decay and insect damage. Where these are obtainable, they are to be recommended providing their odor or other characteristics will not interfere with the insects selected for study. Since the insectaries are floorless, any termite nests that establish themselves among the logs, stumps or in the ground of the insectary are easily removed. Choice plants can always be transplanted if their removal is necessary to get at the nest. We have experienced no difficulty with termites establishing themselves in the ground, probably because the 16 $\times$ 18 mesh screening prevents gravid females from entering the insectary.

The fine mesh screening probably hinders or prevents predators from entering. Any observer is most appreciative of its efficacy in keeping mosquitoes and various biting flies out.

Many scientists would find it helpful to have as a reference book one of the many "Do It Yourself" handyman books that are on the market. Any book giving instruction in constructing small houses or garages will give useful detail.

It will probably be found necessary to have water available. At Trinidad during the dry season daily watering of both screening and plants was a necessity.

If photographic work is anticipated, electrical outlets should be installed in the insectaries. These should all be waterproof.

A baffle would be an improvement to the insectaries. This is particularly true of the small insectaries where great care is often needed to enter and leave without permitting the escape of one of the specimens.

A small pool or stream might be a valuable addition within the insectary. It would be a "must" if one were studying Odonata, for instance, and might be a valuable temperature and humidity regulator for some insects found in the vicinity of water.

III. Shelter and Planting

We soon found that an open air cage of adequate dimensions and proper construction was only the beginning of the requirements for a successful insectary. The additional essentials were the following: shelter from excessive wind and sun which must not interfere with ample sun and alternating patches of light and shade; relative humidity at all times above 55% (maintained by afternoon hosing); growing plants in a variety of size, kind and density; plenty of conspicuous perching places, such as dry branches with small twigs; and an ample supply of fresh food. We did not find any necessity or desirability for cloth mosquito netting in place of wire in order to avoid damaged wings. Those species which were not adaptable to cage life, continuing to bat wildly against the screen, were not suitable for our work, and the saving of perfect specimens was not one of our objects. In any case, cloth would rot too quickly in the tropics to be practical.

In newly built or temporary cages, simple makeshifts served as combination sunshades, windbreakers, storm shelters and approximations of natural greenery. Freshly cut bamboo poles, fastened against one or more of the walls a few inches apart proved excellent; we have kept them permanently against the north and west walls of the large insectary. Here, in addition to affording protection against the weather, they also discourage the flapping of new inmates against the lightest sides of the netting. Split bamboo poles are also laid across the struts of the two shady sections of this house (see below), slat fashion; they reduce the light effectively and serve as an arbor for flowering vines. *Heliconia* and banana leaves as well as some kinds of palm fronds are useful temporarily, but must be often renewed; they may be held in place by furring across the walls and on the roof (Pl. III). However, to preserve the character of the out-of-doors they should be as restricted as possible. Although either strong winds or blazing sun may be quickly fatal to butterflies, a cage divided sharply into glare and deep shade does not encourage normal behavior in most species.

The smaller house was finally protected as follows from sun and wind. The east end stands close to a five-foot embankment; from this rises a mahogany tree which, arching high over the cage, gives ideal partial shade during the morning. Afternoon sun and wind are checked by heavy vines planted outside the west end and allowed to cover about a fifth of the roof. Open sky shows through the middle section of the roof and the green of the garden and surrounding valley is seen through the long side walls.

An ideal arrangement has been attained in the larger house (Pl. IV). This insectary is divided, by degree of illumination, into three sections from north to south, rather than east to west, so that at all times of the day there are two shady sections with an open one between. The end portions are permanently shaded by the bamboo slats at eave level described above, as well as by vines growing both outside and inside the cage; the middle section, together with the "lofts" above the ends, form a brilliantly lighted open space for sun-lovers and high-fliers; it also is particularly useful for photography.

Because both houses are partially wind-protected by the surrounding mountains, as well as by nearby trees and laboratory buildings, far less trouble is given by the spring tradewinds than would be the case in the open flat land, such as we found in our temporary station in Surinam. Here wind was our greatest problem, and one and a third walls of the house had to be solidly covered. By using white canvas for the windiest corner, rather than leaves, adequate protection was finally attained without unduly reducing the light. Also, the butterflies did not avoid the canvas and in fact roosted near it at night (Pl. V, Fig. 9).

The selection and arrangement of growing plants in the insectaries proved to be of primary importance. They were needed for shelter from sun, wind and rain, as remarked above; it was also desirable to have natural food—both flowers and caterpillar food-plants—growing to simplify feeding and oviposition problems. Another factor, however, is involved which is still not understood: large patches of bare, sunbaked ground have proved deadly to our butterflies, presumably because of certain infrared reflections (Querci & Romei, 1946); perhaps, too, there are additional factors, such as color, in the living plants that favorably affect butterflies, either through their sense organs or physiologically. At present we know only that until most of the bare earth in an insectary is covered at least with moderately fresh leaves or, ideally, with a normal variety of growing herbs and shrubs, the butterflies die. In temporary emergencies (as in Surinam) patches of sod work promptly and well.

If possible, the houses should be fully prepared before any insects are introduced. As in regular gardens, adequate drainage should be arranged and the soil appropriately prepared, depending on its natural character and on the requirements of the plants to be grown. In our Trinidad location drainage is automatic as the substratum is porous limestone; because topsoil is practically absent in this site, however, a thin layer of well-rotted manure was found suitable for various desirable local weeds. Special holes were then dug and filled with topsoil and manure for selected plants, both wild and cultivated. Since these beginnings, chemical fertilizers, leaf mold and additional well-rotted manure are used when indicated. Potted plants are always useful both as temporary greenery in new cages and later when special larval food plants are needed for oviposition.

In the Trinidad insectaries the blue-and-white flowering vine *Thunbergia* was planted for rapidly growing shade, both inside and outside the cages, thanks to the suggestion of Dr. F. J. Simmonds. It thrives so luxuriantly that our only care is to keep it under control. Another easily grown though slower vine is the orange-flowered *Senecio* sp., which serves both as shade and as butterfly food. Several species of passion vine (*Pasiflora*), the food of *Heliconius* larvae, also do well. Lantana bushes (*Lantana camara* Linnaeus), a butterfly favorite for food and perches, grow well in the sunniest parts of the cage, but even here do not flower profusely under the screening. Spanish needles (*Bidens pilosa* Linnaeus) and the tropical milkweed (*Asclepias curassavica* Linnaeus) both thrive and serve as food for many butterflies. In addition, *Asclepias* is the larval food plant of the tropical monarch (*Danaus plexippus megalippe* (Huebner)). Further specific suggestions for planting are unnecessary, as tropical conditions are so variable.

From the first an easy and useful type of "planting" is simply the tying of orchids and bromeliads in numbers on the crotches of freely forking branches. These are leaned at intervals against the walls inside the cage and at once give the beginnings of a normal-looking environment, even though few of the plants are attractive to butterflies when in bloom. Their main function, aside from the prompt furnishing of greens and perching places, is in helping to maintain the necessary high humidity. During the hosing down of the insectaries on hot afternoons, it is simple to fill the small reservoirs formed by the bases of the leaves. Many of these epiphytes take root, thrive and seed themselves; at the least they stay green and hold for weeks their reservoirs of water.

In the rainy parts of the tropics, where plant growth is lush and where the butterfly investigator's primary gardening object is to encourage the "weeds," gardening in an insectary is largely a pleasure. When pests do occur, however, their eradication is particularly difficult, as insecticides are dangerous also to the butterflies. In these cases it is necessary either to take out the affected plants, such as aphid-infested milkweed, or to remove the butterflies for a period. The latter procedure was advisable, for example, when termites appeared in the rafters of the small insectary (p. 167). At these times, the advantages of maintaining two cages are obvious.

IV. Stocking

Butterflies are netted in the usual fashion, extra care being taken not to injure them during either capture or removal from the net. Glassine envelopes, piled loosely in boxes, are used to bring the insects alive from the field. A few individual *Heliconius* and *Papilio* have been kept up to 24 hours in envelopes without apparent ill effects, although it is best to release the insects as soon as possible. It is important that the envelopes never be exposed either to direct sunlight or to unduly high temperatures. For example, they should not be carried in a part of the knapsack that touches the body, left in a closed parked car, or placed in the car's glove compartment. Before their release into the insectary, the butterflies may be individually marked for future recognition. We use fast-drying Floquil enamel (available at art stores) in a variety of bright colors, applied in dots on the under wing surfaces. It is advisable to work quickly, to hold the insect by the wing bases rather than by the thorax, and to paint near the centers of the wings. When marks are placed near their tips these apical mmbranes soon fray away.

After handling with the care described above, many butterflies fly off a few seconds after being released in the insectaries. Others remain immobile in a kind of shock for hours, but subsequently recover fully and live many weeks. Relatively few individuals die without regaining their power of flight.

V. Feeding

The plants blooming at any one time in the insectaries are usually insufficient to feed the thriving populations, although the flowers serve well as supplementary and emergency rations. As a staple food, the cut blossoms of wild *Lantana camara* Linnaeus, a favorite with many butterflies, are used. The flowers are gathered early every morning with fairly short stems; they are then arranged in jars of water on a bench. Other blossoms, especially garden *Ixora* which is popular with pierids and *Papilio,* are also used as available. Fresh flowers should always be supplied in abundance, as captive butterflies feed more freely than in the field, and the stimuli from a plentiful food supply seem to be an important factor in keeping them actively flying about.

Some genera in captivity live mostly or altogether on fruit, for example *Euptychia, Biblis, Prepona, Morpho* and *Caligo*. For these, ripe bananas, mangoes and cashews are especially attractive. Fermentation should be avoided; not only do the butterflies show the usual temporary effects, making behavior studies impossible, but the insects apparently may be eventually poisoned and die.

Artificial flowers, similar to those used by Ilse (1928) and David & Gardiner (1952), are used successfully in experimental work. However, the abundance and higher efficacy of natural food make its use in the tropics preferable for daily maintenance.

As shown by Ilse (ibid.) and Tinbergen, etc. (1943), different species of butterflies differ in the stimuli required to release and direct their feeding responses. These responses to color, form and odor in tropical butterflies will be discussed in later papers. Here it is pertinent to remark only that when food preferences of a species are unknown and a butterfly will not feed unaided, forced feeding should be used only as a last resort. It is best first to coax it by bringing close to it a wide variety of natural foods, as additional handling may kill a butterfly already in poor condition. A drop of honey solution pipetted on a corolla and brought against the coiled proboscis often induces feeding in a shocked specimen. Another helpful method is to take advantage of the well known reflex whereby, in some families, the proboscis uncoils when the forefeet are placed in honey or sugar solution (e.g. Roeder, 1953). Finally, if all other methods fail, the proboscis should be uncoiled with a needle and as gently as possible placed in the honey. The wings may be held during this operation by a spring clothespin, as suggested by Norris (1935). We cannot too strongly emphasize, however, the importance of avoiding all possible handling of butterflies intended for work on behavior; although such manipulated specimens may be kept alive for days, they are useless for the desired purposes. Fortunately, these emergency feeding measures are rarely necessary. Most butterflies belonging to species which live well in captivity start to feed without aid within minutes or hours, and will usually become so "tame" that they will soon climb on flowers or fruits held close to them, or even on an adjacent finger, and may then be carried at will about the cage.

When the butterflies are inactive during dark and rainy spells, feeding and flight activities may be stimulated by a row of strong electric light bulbs, sheltered by vines and placed close above the jars of food flowers.

VI. Predators

Although predators of various kinds cause trouble in the insectaries, only orb-weaving spiders and ponerine ants are serious offenders. The spiders especially thrive, as they are freed from their own avian predators. The only way they can be controlled, since insecticides cannot be used (p. 167), is by daily vigilance, particularly early in the morning when the webs, outlined in dew, can easily be seen. The large ponerine ants attack resting or weak butterflies, chiefly on the screens, but sometimes lie in wait on the food bouquets. Fortunately, they are merely an occasional menace. A constant annoyance are the small scavenger ants that promptly carry off freshly dead butterflies, leaving only scattered wings; because of them specimens wanted for the collections must be carefully watched and removed at the first sign of weakness.

Although other predators occur occasionally, including mantids, carnivorous grasshoppers and several species of lizards, all of these are easily removed. Columns of army ants have passed through our insectaries twice, but have not yet attacked the butterflies. Birds never try to seize them through the fine-mesh screens, although very rarely hummingbirds attempt to reach the flowers.

VII. Population Regulation

The maximum number of butterflies we have kept alive simultaneously in an insectary was 36, consisting entirely of *Heliconius* spp. This occurred in our small 12′ x 15′ temporary cage in Surinam, where this total was kept for three days at the conclusion of our stay, after which the butterflies were killed while still in good health. However, experimental work could not be properly done under these conditions, as crowded butterflies tend to stimulate each other to excessive activity. In the permanent installations in Trinidad the small insectary held comfortably up to 20 butterflies for long periods; for experimental work we limit them to ten. The large insectary supports correspondingly more, although its maximum capacity has not yet been tested.

As most of the experimental work is done on the gregarious heliconids, probably the numbers quoted above are larger than would be desirable in working with strictly solitary forms. Nevertheless, there is a definite advantage in keeping a moderately large number of butterflies, even of various unrelated species. Apparently the sight and perhaps the odor of their flying fellows tend to stimulate them mutually to normal flight and feeding.

One important aspect of this subject concerns the "seasoning" of an insectary by the mere presence of other butterflies. This is especially true of gregarious forms such as *Heliconius*. In this genus individuals which are already established actually seem to act as decoys for the newcomers, since the latter stop their initial batting against the screen and begin to feed much sooner than when placed in an empty cage. However, even empty cages which have recently held members of the same or related species have a noticeably calming effect on new arrivals, in comparison with cages which have long been vacant. Their customary selection of identical twigs for perching or roosting strongly suggests the lingering of odors from previous inhabitants.

VIII. Summary

Three outdoor insectaries are described which have been successfully used in Trinidad and Surinam in the study of butterfly behavior. They measure 12′ x 15′, 12′ x 18′ and 24′ x 33′, have gabled roofs and range in height from 9′ to 10′6″ at the ridgepole. They are constructed entirely of fine-mesh bronze wire screening attached to wooden frames and set, except for low concrete foundations, directly on the ground. The soil within and about the foundations is prepared for the cultivation of the variety of herbs, shrubs and vines which have proved essential to establish and maintain an active butterfly population. These growing plants are the best means of controlling the sunlight, shade, temperature and humidity; they also provide the necessary protection against the wind and rain. As temporary or supplementary measures, fresh-cut leaves, branches, bamboo slats and canvas sheets may be used. Bare ground in sunny parts of an insectary is fatal to butterflies. Specimens intended for the insectaries should be handled as little as possible after netting, stored in glassine envelopes until their release and kept away from both the sunlight and excessive heat. Most species which adapt themselves well to confinement feed freely when provided with ample natural food, whether flowers or fruit. Control measures against predators and pests, such as spiders, ants and termites, are discussed. It is recommended that populations which are subjects of behavior studies be restricted to about ten active individuals.

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EXPLANATION OF THE PLATES

PLATE I

FIG. 1. Construction of large insectary, 24′ × 33′, Simla, Arima Valley, Trinidad.

FIG. 2. Same.

PLATE II

FIG. 3. Same, completed.

FIG. 4. Small insectary, 12′ × 18′, Simla, Arima Valley, Trinidad.

PLATE III

FIG. 5. Temporary insectary, 12′ × 15′, Moengo, Surinam. Note windbreak of *Heliconia* leaves.

FIG. 6. Interior, showing minimum essential furnishing, including sod, branches and fresh flowers.

PLATE IV

FIG. 7. Interior of large insectary, Trinidad, showing general arrangement of planting and alternation of light and shade.

FIG. 8. Corner of same in shadiest portion. Note arrangement of bamboo slats, luxuriance of vines and variety of ground cover.

PLATE V

FIG. 9. *Heliconius* spp. going to roost in temporary insectary, Moengo, Surinam.

FIG. 10. *Dryas julia julia* Fabr. feeding from *Lantana camara* L. inside insectary, Simla, Trinidad.